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Remarks:

1. The Examiner has required a new title that is clearly indicative of the invention to which the claims are directed. Applicant has amended the title accordingly to read "Interferometric Back Focal Plane Scatterometry with Koehler Illumination." Applicant has further replaced the phrase "back plane" with the phrase ---back focal plane--- at three occurrences in the claims to more consistently point out his invention.
2. The Examiner has objected to the inventor's spelling of "Mirau." The requested change has been made throughout the application.
3. Claim 20 is rejected for the reason that the term "quasi-monochromatic" conflicts with claim 7, from which it depends, which required simultaneous multiple wavelengths. Applicant does not agree that there is a conflict. The term "quasi-monochromatic" refers to narrow bandwidth sources, which contains multiple wavelengths within a limited bandwidth. Nonetheless, in response, applicant has amended claims 20 and 34 to replace the term 'quasi-monochromatic" with more descriptive language as follows:
 20. (amended) An interference spectrometer as in claim 7 wherein the source is a source of illumination within a limited bandwidth and the limited bandwidth is less than the bandwidth of the visible spectrum.
 34. (amended) An interference spectrometer as in claim 21 wherein the step of providing Koehler illumination provides

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illumination within a limited bandwidth and the limited bandwidth is less than the bandwidth of the visible spectrum.

4. Examiner rejects claims 1-10, 19, 21-24 and 33 under 35 U.S.C. 102(b) as being clearly anticipated by Davidson et al (USP 5,112,129). As the Examiner notes, in the Davidson et al patent (USP 5,112,129), camera (22) (is) located at the image plane (36). (Figure 1 of '129) Further, he notes “a plurality of images are captured by the camera and stored in memory, wherein each pixel of an image corresponds to a location on the wafer surface, see figure 7”. The camera in Davidson '129 is thus positioned to record an optical image of the *image plane*.

Similarly, Examiner rejects these same claims under 35 U.S.C. 102(b) as being anticipated by deGroot (USP 5,398,113). The rejection of the additional claims in view of deGroot is addressed below.) As the Examiner notes, the deGroot patent (USP 5,398,113) recites, “The computer includes capturing a plurality of images....and storing each image in memory, wherein *each pixel of an image corresponds to a location on the sample surface....*” [emphasis added] Quoting from the '113 specification: “An objective lens 10 and a camera lens 11 focus the image of the object surface 3 onto the array 9 so that each element of array 9 corresponds to a respective point or small region or location of surface 3. Additionally, a lens 12 is used in conjunction with camera lens 11 to image the reference surface onto the same detector array 9.” The detector array in deGroot '113 is thus positioned to record an optical image of the *image plane*.

Davidson '129 and the deGroot patent both teach *imaging the object (the image plane)*. To be more precise, the Davidson and deGroot patents teach imaging the object plane of the objective lens onto the detector array/camera. Recording an image of the *image*

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plane is necessary to the purposes of the Davidson and DeGroot patents, which are directed to *imaging systems*.

In contrast, the present invention is a scatterometer, not an imaging system. Specifically, independent claim 1 of the present application specifically recites “a detector positioned to record an optical image of the *back focal plane* of the objective lens.” [emphasis added]. [The phrase “back plane” has been amended to read --back focal plane-- to provide greater consistency in the claims.] Likewise, independent claim 21 of the present application specifically, recites “detecting an image of the *back focal plane* of the objective lens.” [emphasis added] Claims 1 and 21 specifically recite apparatus and methods that *image the back focal plane of the objective lens onto the detector/camera, as distinct from the imaging of the image plane as taught in the cited prior art.*

The difference between recording the image of the image plane and recording the image of the back focal plane is significant. As claimed in the present invention, capturing the image of the back focal plane enables the measurement of the specular reflection at different angles of incidence. Recording the image of the image plane does not provide this advantage. In fact, once this is done, as taught in the cited prior art, the ability to measure the specular reflection at different angles of incidence is lost.

Imaging systems do not use the back focal plane because it is badly “out-of-focus” from the perspective of the desired image. In fact, using an “out-of-focus” image would defeat the purpose of cited prior art, which is to obtain high resolution images of object surfaces. [In fact, the image of the back-focal-plane is in fact the most out-of-focus plane possible if what is desired is an image of the object.]

5. Applicant notes that claims 11-12, 25-26 and 34 are rejected only in view of deGroot and that in deGroot “a Fourier transform is applied to each image ...thus applying the

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principles of frequency-domain analysis to topography. However, deGroot does not use the same information, nor does deGroot calculate the same results. In particular:

Claims 10 and 24 recite “each channel corresponds to a single location on the back focal plane....”

Claims 11-12 and 25-26 recite “to determine specular reflection coefficients...”

The DeGroot patent uses data from the image plane in a frequency domain analysis. This data corresponds to locations on the image plane. These locations do not correspond to locations on the back focal plane. In fact, this information is lost once the image is recorded. Further, deGroot does not teach calculating the specular reflectivity off of a surface as a function of both angle and wavelength simultaneously.

In explanation, when the object is imaged onto the detector array, as in DeGroot, all the angles of light emitted from a point on the object are focused onto a small area (or even one pixel) on the detector array. The light coming from the surface at all different angles is thus mixed together. Once this occurs, it cannot be separated by subsequent calculations done on the data which is captured by the detector array in this case. The spatial frequency distribution which deGroot calculates at each pixel involves a mixture of light coming from the surface at different angles and different wavelengths. Thus, DeGroot’s configuration can not distinguish between specular and non-specular scattering off of an object. Accordingly, DeGroot is incapable of determining specular reflection coefficients as recited in claims 10-11 and 25.

Accordingly, Applicant submits that all claims 1-12, 19-26, 33 and 34 are allowable in view of either the Davidson ‘129 or the deGroot references.

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6. Examiner rejects claims 12, 13, 20, 25-27, 34 under 35 U.S.C. 103(a) as being unpatentable over Davidson et al (5,112,129) in view of deGroot (5,398,113). Examiner states that “It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the Davidson apparatus to applying the principles of frequency-domain analysis to tomography to improve tomographic measurements.”

Applicant respectfully traverses. His invention is not directed towards tomography (the imaging of selected planes) and the claims distinctly distinguish from such imaging systems. Imaging systems such as the cited prior art image the image plane/object.

In contrast, the present invention distinctly claims imaging the back focal plane. Imaging the back focal plane onto the camera or detector array is a radical and non-obvious choice for a microscope system, especially ones with high numerical aperture. This is because most microscope systems are designed to image an object. However when recording the back focal plane of an object, the object is completely out of focus and there is no recognizable image. Thus imaging systems do not record the image at the back focal plane.

However, there is an unexpected advantage to recording the back image plane in scatterometry/spectroscopy. *This is because different points in the recorded back focal plane correspond to different angles of rays leaving the object.* Moreover, if Koehler illumination is used a further advantage is obtained because any non-specular scattered light will be detected at a different point in the detector array than specularly reflected light, making it incoherent relative to the light specularly reflected from the reference mirror. Thus, only specularly reflected light will survive the Fourier transform algorithm, allowing one to cleanly calculate the complex reflectance as a function of angle and wavelength from the data gathered by the camera as is shown in the current patent. This

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is a distinct advantage for film thickness and scatterometry measurements, and is not possible with the techniques of deGroot, Kim et al, or Davidson et al because they do not record images of the back focal plane. Further, while it may be obvious to improve the imaging of Davidson by using the frequency domain techniques of deGroot, there is no suggestion that the combination of references makes it obvious to either image the back focal plane or to use such an image for the purpose of determining specular reflection coefficients.

Finally, applicant has submitted the reference "Interferometric back focal plane microellipsometry" by Feke et al. in conformity with 37 CFR 1.97. A form PTO/SB/08B (08-03) is also enclosed. In the Feke et al. reference the back focal plane is illuminated by a coherent laser beam. This is distinct from the Koehler illumination recited in the claims. In conformance with 37 CFR 1.97(e) I certify that:

The Feke et al. reference was not cited in a communication from a foreign patent office in a counterpart foreign application, and, to my knowledge, after having made a reasonable inquiry, it was not known to any individual designated in § 1.56(c) more than three months prior to the filing of the information disclosure statement.

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Applicant respectfully submits that the claims of the present application clearly distinguish from the cited prior art, and that the cited prior art does not anticipate or even hint that the adaptation of an imaging system by illuminating the object with Koehler illumination and recording the image of the back focal plane makes it possible to develop an improved scatterometer. Accordingly, applicant requests the allowance of the claims as amended.

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Michael L. Sherrard Date
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